



Re-verification of the IRHN57133SE and IRHN57250SE for Single Event Gate Rupture and Single Event Burnout

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EXECUTIVE SUMMARY

Test results for hi-rel total dose hardened power MOSFETs, manufactured by International Rectifier on its new fabrication line in Temecula, California, are presented in this report. The IRHN57133SE and IRHN57250SE were tested to NASA test condition standards and requirements. The IRHN57133SE performed poorly when compared to the previous test data, while the IRHN57250SE showed considerable gains over parts of similar voltage and current rating. From these two tests, the initial results are that parts from the Temecula line are marginally comparable to the El Segundo line. Both parts experienced single event gate rupture (SEGR) and single event burnout (SEB), and all of the SEGR was from gate to drain. This observation is different from previous testing where devices exhibited gate-to-source SEGR.

Since one of the two parts tested demonstrated an increased single event effect (SEE) response when compared to the same part from the previous fabrication line, it is recommended that all devices from this fabrication line be screened for SEE.

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1.0 INTRODUCTION

The vertical metal oxide semiconductor field-effect transistor (MOSFET) is a widely used power transistor onboard a spacecraft. The MOSFET is typically employed in power supplies and high current switching applications. Due to the inherent high electric fields in the device, power MOSFETs are sensitive to heavy ion irradiation and can fail catastrophically as a result of single event gate rupture (SEGR) or single event burnout (SEB). Manufacturers have designed radiation-hardened power MOSFETs for space applications. These radiation hardened devices are not immune to SEGR or SEB but, rather, can exhibit them at a much more damaging ion than their non-radiation hardened counterparts. See [1] through [5] for more information.

This effort was to investigate the SEGR and SEB responses of two power MOSFETs from IR (the IRHN57133SE and the IRHN57250SE) that have recently been produced on a new fabrication line. These tests will serve as a limited verification of these parts, but it is acknowledged that further testing on the respective parts may be needed for some mission profiles.

2.0 TEST METHOD

The test devices chosen are listed in Table 1. All SEE tests were conducted in accordance with reference [6]. However, for the IRHN57250SE, the post-irradiation gate stress (PIGS) test between irradiation runs was only the next voltage increment between irradiation runs, instead of the full derated value.

2.1 SEE Beam Parameters

Devices under test (DUTs) were irradiated at Brookhaven National Laboratory and the Texas A&M Cyclotron. All irradiations were performed at normal incidence.

2.2 Device Characterization Prior to Irradiation

Prior to any irradiation the devices were electrically characterized using a Tektronix 371b curve tracer. Non-destructive electrical measurements were performed on all devices: specifically, the threshold voltage (V_{th}) and the transconductance (g_m). If either of these parameters were not in specification, the part was excluded from the test population. Parts were de-lidded with a micro-mill and remeasured after de-lidding to verify no damage occurred in this process.

2.3 Experimental Setup

Figure 1 shows the schematic of the experimental setup used during the SEE testing. All devices were biased and measured with the HP4142B Modular DC Source/Monitor Unit (SMU) connected to a personal computer (PC) via a general-purpose instrument bus (GPIB). SMUs were used with 24-in coaxial cables that could source current with a current limit of 10 mA, with no stiffening capacitance or choke inductance added into the test circuit. The type of SEE (gate-to-drain SEGR, gate-to-source SEGR, or SEB) was noted as well as the fluence at the voltage in

Table 1. Parts Used in this Study

Part Number	Voltage rating [V]	RDSon [Ω]	Current rating [A]	Type	Number Tested	Package
IRHN57250SE	200	0.06	31	N	25	SMD-1
IRHN57133SE	130	0.08	20	N	25	SMD-0.5

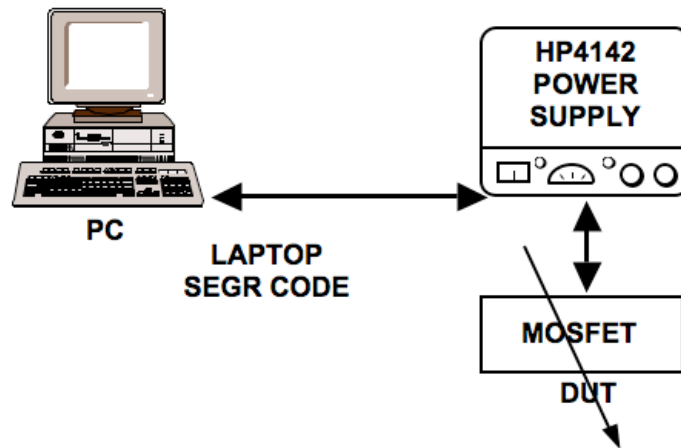


Figure 1. Schematic of Experimental Setup

which the SEGR/B occurred and the total fluence the part endured. The current and voltage changes were measured at approximately 100-ms increments; the maximum current resolution of the SMU was 1nA. Background noise in a virgin device typically had an amplitude of <10nA.

2.4 Failure Condition

SEGR was defined as the drain-to-source voltage at which the current from gate-to-drain or gate-to-source permanently exceeded $1\mu\text{A}$; this variable is called V_{crit} . The mean SEGR voltage value was determined by computing the arithmetic average of the V_{crit} value and the previous voltage. Since the definition of the SEGR voltage is the average voltage at which the DUT exhibited an SEE and the voltage of the previous irradiation, a valid data point is one where the DUT exhibited no failures (SEGR or SEB) for at least one complete irradiation run. One type of SEGR occurs when the gate and drain currents exceed $1\mu\text{A}$; the source current is not altered by the catastrophic event, i.e., the large current is from gate to drain. SEGR can also manifest itself as high gate and source currents that exceed $1\mu\text{A}$, while the drain stays intact. SEB, on the other hand, exhibits a high source-to-drain current. The functionality of the gate is retained following the event. However, current control is no longer possible as the properties of the semiconductor have been damaged.

2.4.1 Error Bars

The voltage steps (system resolution [SR]) were chosen to be 5% of the device voltage rating. The error bars associated with each data point on the safe operating area (SOA) curve were computed by taking the square root (SR) of the sum of the squares of the uncertainty in each measurement and the standard deviation (SD) of all measurements on multiple device samples performed at the specific V_{DS} and V_{GS} bias condition.

3.0 RESULTS

Overall, the parts performed comparable to previous part types. All of the SEGR were of the gate-to-drain type. Part-to-part variation was an issue for both parts, but not more than typically seen in other similar parts. This is an important observation in that parts on the El Segundo line have demonstrated some gate-to-source SEGRs. The fact that the Temecula line did not exhibit

any gate-to-source SEGR might be the result of changes in the process as well as the line. The data were straightforward when they were taken; that is, no microbreaks, dose effect, or other anomalies were observed.

3.1 IRHN57250SE

These parts performed better than others of this device rating. Figure 2 shows the gold ion data and Figure 3 shows the bromine and krypton data. Note that the range of the bromine just meets NASA requirements, so some data points were taken with krypton to confirm. The krypton data were identical to the bromine data. Note that the device is out of absolute maximum ratings to induce SEE with bromine or krypton. In discussions with International Rectifier, it was revealed that the only the specified absolute maximums are guaranteed by testing at IR while the breakdown out of specification is not known due to manufacturing variance. Therefore, the strongest statement about Figure 3 is that the part is immune to SEE at a linear energy transfer (LET) of $\sim 37 \text{ MeV.cm}^2/\text{mg}$.

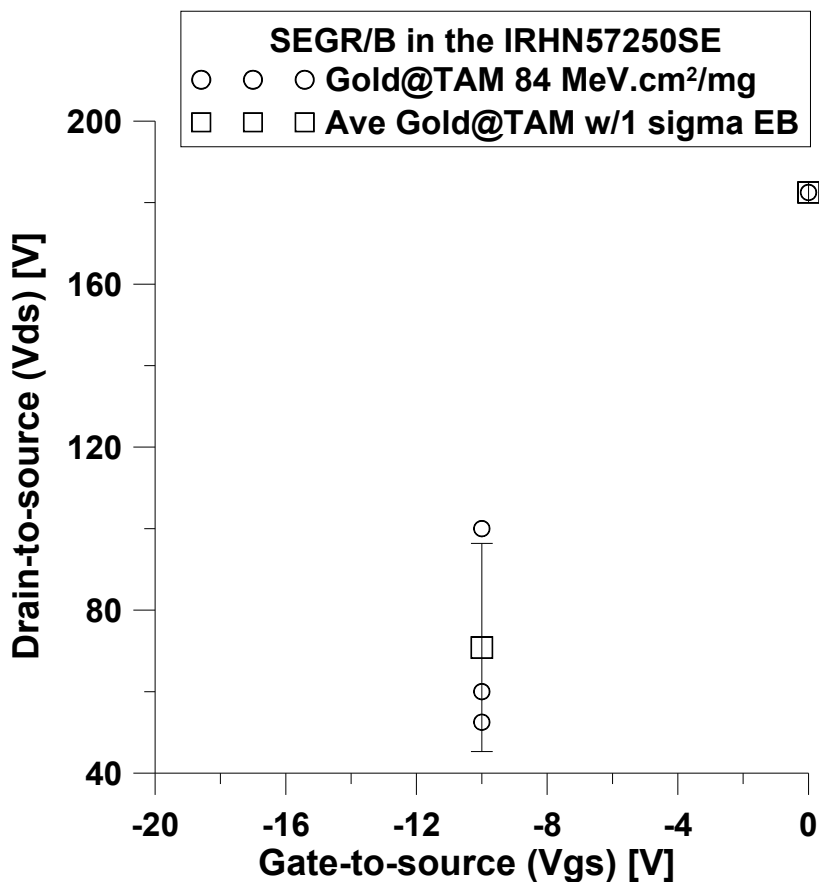


Figure 2. SEE response of the IRHN57250SE for gold ions.

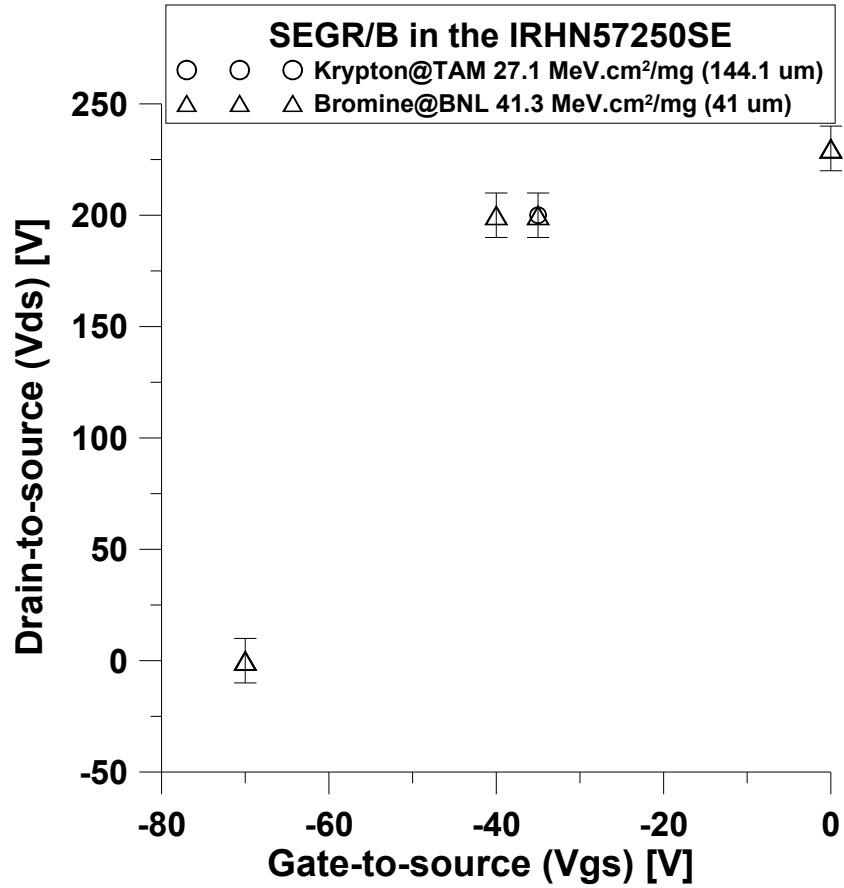


Figure 3. SEE response of the IRHN57250SE for bromine (BNL) and krypton (TAM) ions. Note that the device had to be taken out of specification to induce SEE.

3.1.1 Comparison to El Segundo Parts

Shown in Figures 4 and 5 are the closest parts taken from the El Segundo line that JPL has tested. The results from the Temecula line demonstrate a much more robust part.

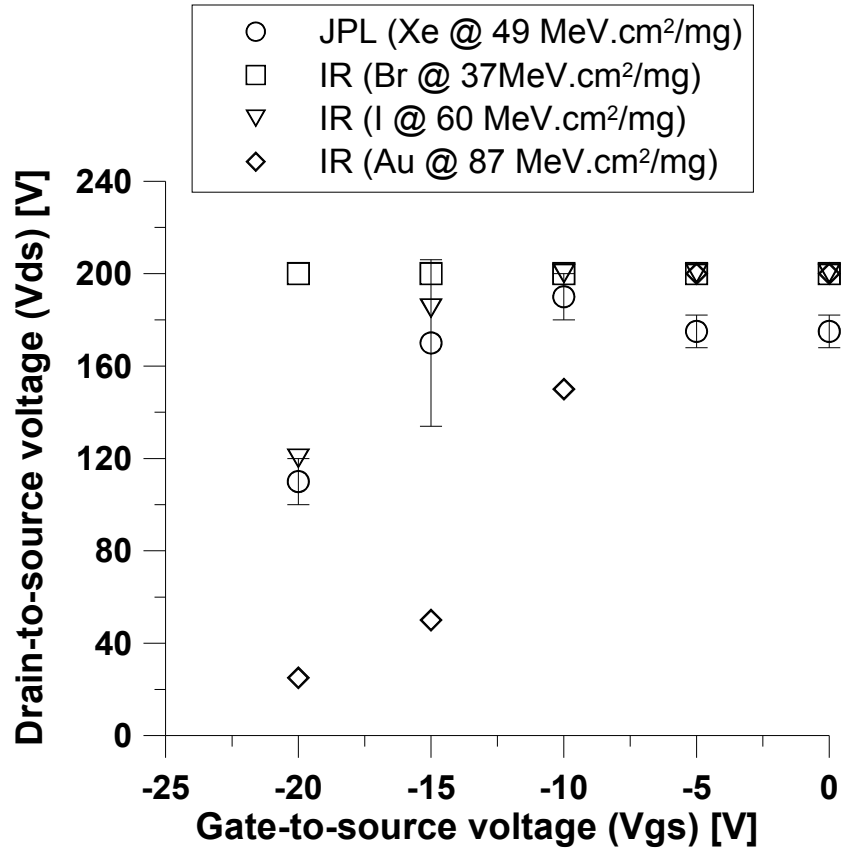


Figure 4. SEE results for JANSR2N7498T2 (N-Channel) from the El Segundo line.

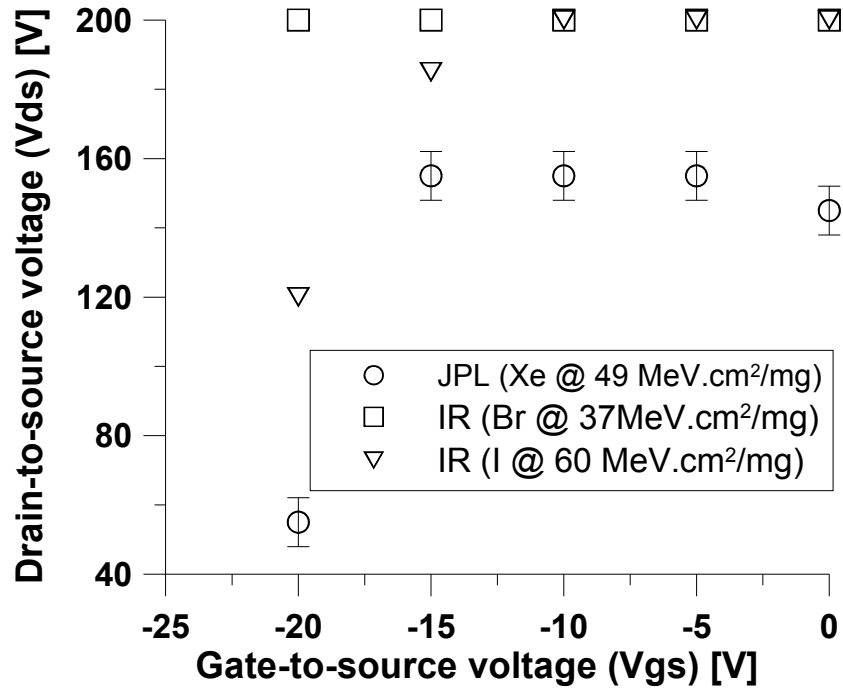


Figure 5. SEE results for IRHMB57260SE (N-Channel) from the El Segundo line.

3.2 IRHN57133SE

Figure 6 presents the test results of the Temecula line parts for the IRHN57133SE.

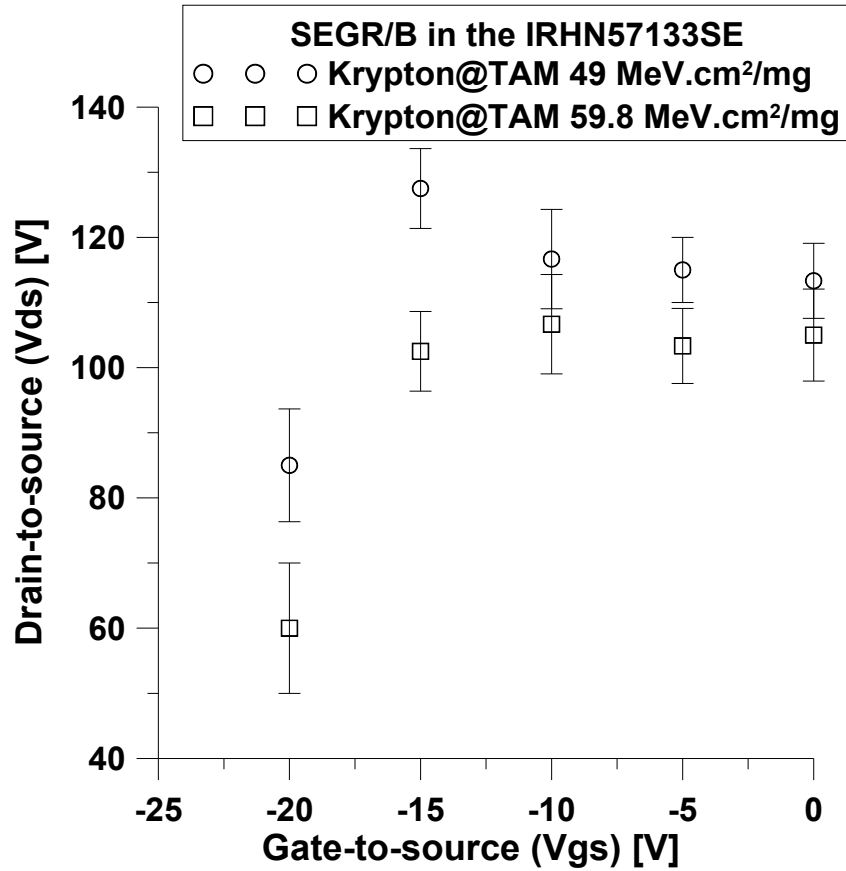


Figure 6. SEE results for IRHN57133SE (N-Channel) from the Temecula line.

3.2.1 Comparison to El Segundo Parts

Figure 7 presents data taken from the El Segundo line that JPL has tested. These parts performed poorly when compared to the part previously tested from the El Segundo line. The krypton was tuned for some measurements to match the surface LET of the ion used in IR's previous testing.

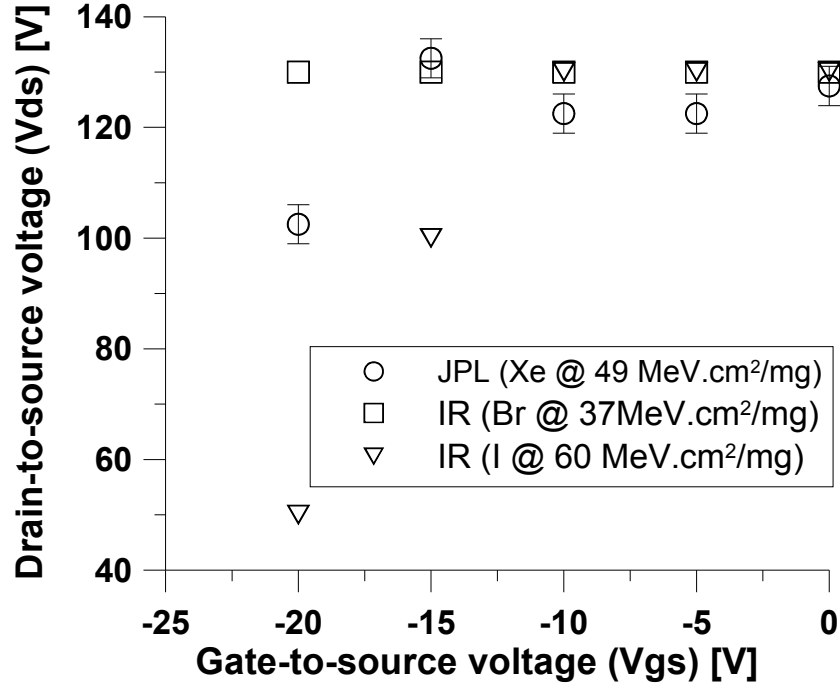


Figure 7. SEE results for IRHN57133SE (N-Channel) from the El Segundo line.

4.0 CONCLUSION

SEGR and SEB tests of the new power MOSFETs off the Temecula line have yielded mixed results in comparison with the previous line's parts. The IRHN57133SE performed poorly, that is, exhibited SEE at lower voltages, while the IRHN57250SE performed better. The characteristics of the events were slightly different, so the change to the new line may have been the cause of this observation; however, the statistics are not sufficient for any definitive conclusions.

4.1 Recommendation

Since one of the two parts tested demonstrated an increased SEE response when compared to the previous fabrication line, it is recommended that all devices from this fabrication line be screened for SEE.

5.0 REFERENCES

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